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CITATION:

NIMURA, YOSHIJI. The Electrochordographic Study of the Hemodynamics of the Spinal Cord. 日本外科宝函 1965, 34(4): 833-848

ISSUE DATE:

1965-07-01

URL:

http://hdl.handle.net/2433/206515

The Electrochordographic Study of the Hemodynamics of the Spinal Cord

by

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Received for Publication May 10, 1965

I INTRODUCTION

The spinal cord injuries due to traffic and industrial accidents have increased recently. These facts require the progress of surgical treatment upon the spinal cord.

On the other hand, the diseases related to the disturbances of blood circulation in the spinal cord, such as spinal arachnitis[4)16)] or cervical osteochondrosis, have come into question.

But one of the reasons why the surgical treatment on the spinal cord has been stayed at the most undeveloped level in neurosurgery is due to the fact that its hemodynamics have not been well clarified.

This experiment has been made to clarify the hemodynamics of the spinal cord and to improve the treatment of the spinal cord injuries[11)].

In this experiment, the temporary occlusion of the aorta[1)2)11)18)19)23)24)25)] produced the disturbances of the blood circulation of the spinal cord and evoked electrochordagraph [3)7)8)9)17)19)20)24)], was used as an indicator of the neuronal activity of the lumber cord.

II MATERIALS

1) Experimental animals

The experiment was performed on about fourty healthy adult mongrel dogs. Their body weight was 8.8 kg on an average. The experiment was done in summer and room temperature was 28°C～35°C.

2) Instruments

Potentials from the dorsal surface of the canine spinal cord were recorded photographically from the cathod-ray oscillograph (Nippon-Koden K. K. : V C - 6 Dual - Beam Cathod-ray Oscillograph), and two amplifiers (AVB-1 Biophysical Amplifier) were used. Stimulus was the rectangular pulse obtained from the stimulator and synchronized with the sweeps on the oscillograph.

The reference electrode and stimulating electrode in this experiment were single platinum wire about 0.5 mm in diameter insulated except for the tip, and the indifferent electrode was a metal clip.

To produce the aortic occlusion, the vascular catheter with scale and a balloon was used (Fig. 1). The balloon was inflated by

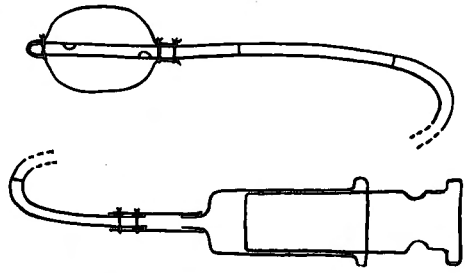


Fig. 1. Catheter with the Scale and Balloon

the physiological saline solution after the tip of the catheter was passed through the femoral artery into the aorta.

III METHODS AND RESULTS

1) Experimental methods

(a) Operations

The dogs were fixed on the ventral position under the intravenous anesthesia of Nembutal (40 mg/kg).

A tube was put into the trachea and oxygen was inhaled, if necessary.

The cardiotonica and hemostatics were injected sometimes.

The dog was laminectomized at a level of the eigth thoracic vertebra and spinal cord was severed at this level. Next, the left sciatic nerve was exposed and cut. The right sciatic nerve was exposed to the level of the distal end of the femur. Then the dog was turned over and fixed on the spine position, the left femoral artery was exposed at the part of Lig. inguinale. After the left femoral artery was incised, the catheter was inserted retrogradely into the aorta and fixed at the various levels The dog was fixed on the ventral position again.

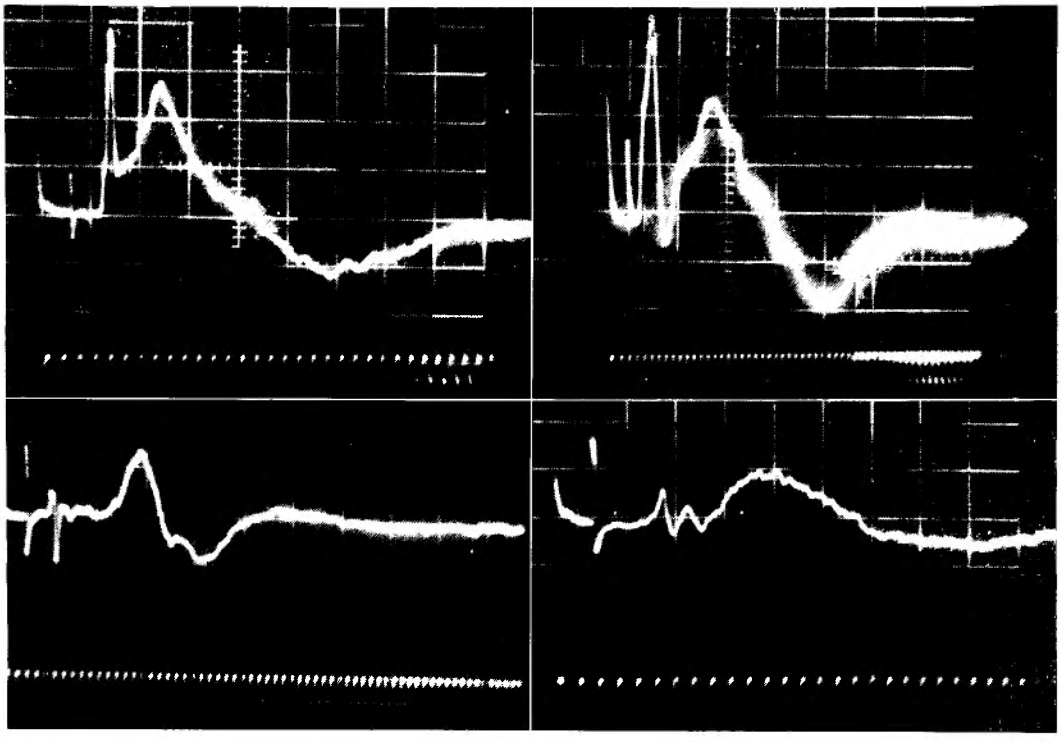
After laminectomising the lower part of the lumbar vertebrae and upper part of the sacrum, cotton moistened with paraffin oil or physiological saline solution was put on the operation part to prevent from drying. The same procedure was done on the exposed right sciatic nerve. Great care was taken during the operation as it took a long time. The dog was almost awaken from anesthesia when the operation had been finished.

(b) Setting the electrodes

Thirty minutes before experiment, the right sciatic nerve was severed at the level of distal end of thighbone, and its proximal tip was placed on the stimulating electrode connected with the stimulator. The reference electrode consisting of spinous platinum wire was placed on the surface of the right side of the spinal cord at the level of the lower part of lumbar vertebrae or the upper part of lumbar vertebrae or the upper part of the sacrum through the dura mater. For this purpose the dura mater was picked up by a small pincette, pierced by the electrode and set free gently. The indifferent electrod (metal clip) was fastened on the muscle adjacent to the spinal cord. After the both leads were connected to the preamplifiers, a stimulus volley was transmitted usually by the rectangular pulse of 0.2 msec duration and about 20 volts. Then the response appearing on the ossillograph was observed. The point wich showed maximum response was detected by moving the different electrode from place to place. This maximum point was regarded as "entry zone". The maximum stimulus was decided by adjasting the stimulation voltage which ranged from about 10 to 30 volts.

(c) Control experiment

The experiments was usually started 5 ~ 6 hours after the thoracic cord has been severed. Before beginning the experiment of the aortic occlusion, the evoked electrochordo gram was recorded as the control. The response forms was varied according to the place where the electrode on the spinal cord was set or according to the individual difference. Especially, the negativ potential (abbr. N) and the positive potential (abbr. P) show considerable individual differences (Fig. 2). For example, the response time of N is



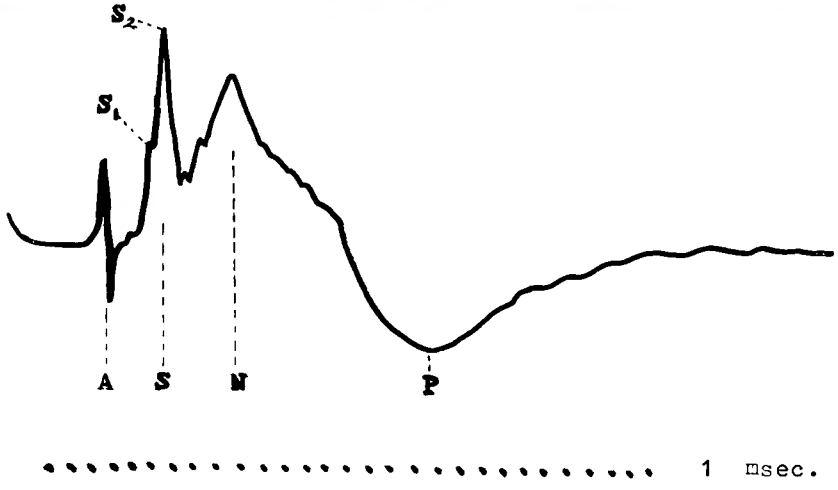


Fig. 2. Various Responses of the Spinal Cord potentials After Stimulating the Sciatic Nerve and the Abbreviations of Each Components

considered about 3 msec, but sometimes shows 8～10 msec and occasionally these do not appear due to the bleeding in operation. But initial positivity (abbr. A) and spike potential (abbr. S) preceding N and P always appeared clearly. This is one of the reasons why S is adopted as the indicator in this investigation.

A shows that the stimulus reached the spinal cord and is considered as an artefact,

because it appeared even after the dog died.

(d) Experiment

The occlusion level in the aorta was decided from the scale on the catheter, and the blood flow was intercepted by inflating the balloon with physiological saline solution. After that the evoked electrochordogram was recorded at intervals. Immediately after the response had disappeared, the blood flow was reopenened by sucking the physiological saline solution in the balloon. The evoked electrochordogram was recorded at intervals after the reopering. After the recovery of the response, in 30 min. to two hours, this experiment could be repeated if general condition of the dog was suitable.

The time period of occlusion required for disappearance of response to stimulation is designated in this report as "disappearance time". The time period required for the recovery of response after the reopening of aortic occlusion is designated as "recovery time".

(e) Autopsy

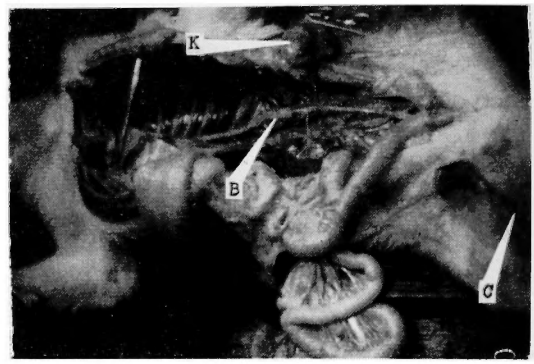
After the experiment, the dog was killed by the air injection and dissected investigating the following points,

i the level of occlusion in the aorta by the balloon (photo. 1)

ii the distribution of the spinal branches from the aorta

iii the length of the sciatic nerve from the cutting end to the lumbar vertebral body.

Photo. 1. Autopsy : Showed the Balloon in Aorta



B : Balloon
C : Catheter
K : Kidney

The spinal branches arising from the aorta are almost similar in size and enter the intervertebral spaces.

A sciatic nerve in proximal part makes a nerve plexus on the lateral side of the vertebral body and the nerve plexus branches off again to enter the spinal tube through the intervertebral spaces from seventh lumbar vertebra to the upper part of the sacrum. Another nerve plexus lying cranial to the ishiadicus includes the femoral nerve and it enters the spinal tube through the lower part of lumbar vertebrae.

The lengh from the cutting end to the side of vertebra was about 20 cm.

2) Experiment (1) The changes of the cord potentials under the temporary aortic occlusion after the aortic occlusion

After the aortic occlusion S, N and P disappeared in the course of time. This course was pursued by the occlusion of the midthoracic aorta.

(a) Experimental method

Experiment was done as mentioned at (d) of III, 1).

(b) Results

As mentioned above, the components of the cord response are influenced by the individual difference or the operative invasion, as showed at Table 1. But as mentioned later, the patterns of cord potentials are nearly the same.

Table 1 Individual Differences of Total Responses

Case		A	A～S	S	A～N	N	A～P	P
1	Amplitude (μV)	100		380		275		135
	Time of duration (msec.)	0.2		1.1		9.5		17.0
	Distance between the tips (msec.)		2.6		6.5		17.5	
2	Amplitude (μV)	185		115		105		45
	Time of duration (msec.)	0.2		2.7		7.6		10.0
	Distance between the tips (msec.)		3.5		8.8		15.0	

Table 2 Spike Potential Immediately After the Negative and Positive Potentials Disappeared

Case	Spike Potential (Amplitue & Duration)	Distance Between the Tops of A and S
1	470 μV 3.3 msec	2.6 msec
2	105 μV 3.7 msec	4.0 msec

On the other hand, S immediately after the disappearance of N and P was shown on Table 2. The amplitude of S increased slightly in many cases. The time of duration was prolonged, while the distance from A to S almost unchanged. The extended time of duration of S is usually apparent, because the latter half of S deflection which was masked by rising phase of N wave, after disappearance of N wave and it impresses the enlargement of S.

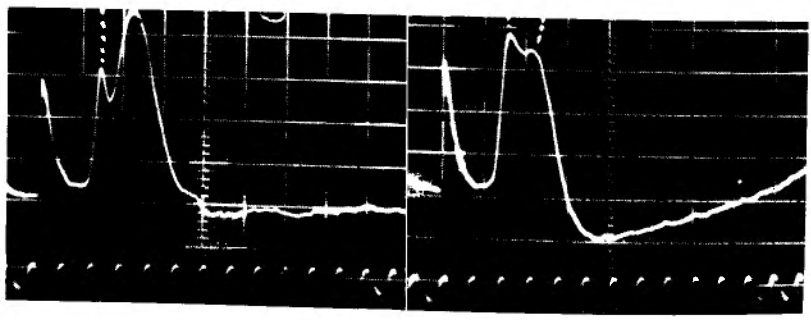
The course of disappearance of S after the aortic occlusion and the course of recovery after the reopening of the occlusion are shown on the Table 3 and Fig. 3. This is one of many cases but the modes of disappearance of S were all the same.

The majority of S has two tips, named S_1 and S_2. An amplitude of S_2 was larger than S_1, and S_2 was relatively more sensitive to the interception of blood flow (anoxia) than S_1. So the time of S_2 disappearance was sooner than S_1. The time of S_1 recovery after the reopening of the blood flow was sooner than S_2. The time of S_2 duration was longer than S_1, since the tip of S_1 is sharper and the descending phase of S_2 gives an easier grade. Very easy positive after-potential appeared after S_2, and continued about 10～20 msec.

As shown on the Table 3, notwithstanding the recovery of S finished in about 20 min., that of N and P did not finish in 90 min. In one case of which the aorta was occluded until S disappeared and waited for three hours after the reopening of the blood flow, N and P did not get a complete recovery. But, the cases in which the occlusion was continued until N and P disappeared (i. e. about 2 min.) and reopened, got a complete recovery in 15 min. after the reopening of the blood flow (Fig. 4). That is to say, in the changes of the cord potentials by the aortic occlusion N and P disappearances were sooner and S disappearance was slower. And in the course of the recovery after the reopening of the blood flow, S began to recover rapidly while N and P recovered very slowly. On the other hand, when the aortic occlusion was repeated in the same

Table 3 Upper . The Diminition of the Spike Deflection After the Aortic Occlusion
Lower : The Development of the Spike Deflection After Reopening the Occlusion

Time	Amplitude (V)	Duration (msec.)	Latent Period (msec.)	Note
Control	380	3.2	1.4	Two tips, $S_1<S_2$
Occlusion				
15″	420	3.0	1.4	〃
30″	410	3.2	1.4	〃
45″	390	3.8	1.6	〃
1′	400	3.8	1.6	〃
1′30″	380	3.2	1.6	〃
2′	360	3.4	1.8	〃
2′30″	310	3.4	1.8	〃
3′	290	3.5	1.8	〃
4′	260	3.4	1.8	$S_1>S_2$
5′	270	3.4	1.8	〃
7′	210	3.4	1.8	〃
8′	170	3.2	2.0	〃
10′	160	3.0	2.2	〃
12′	110	2.8	2.2	Single tip
14′	70	1.6	2.5	〃
15′	20	1.5 ?	2.8	〃
16′	0			Disappearance
Reopening				
5″	0			
20″	80	1.3	1.9	Single tip
30″	90	4.5	1.6	Two tips, $S_1>S_2$
1′	120	5.0	1.8	〃
3′	130	4.5	1.8	〃
5′	170	4.5	1.6	〃
10′	220	4.2	1.8	〃
15′	260	4.8	1.8	$S_1=S_2$
20′	430	4.0	1.5	$S_1<S_2$
25′	430	3.2	1.4	〃
30′	420	3.1	1.4	N-Reappearance
40′	370	2.8	1.3	
60′	380	3.0	1.5	P-Reappearance
90′	390	2.8	1.4	N & P Yet Uncomplete



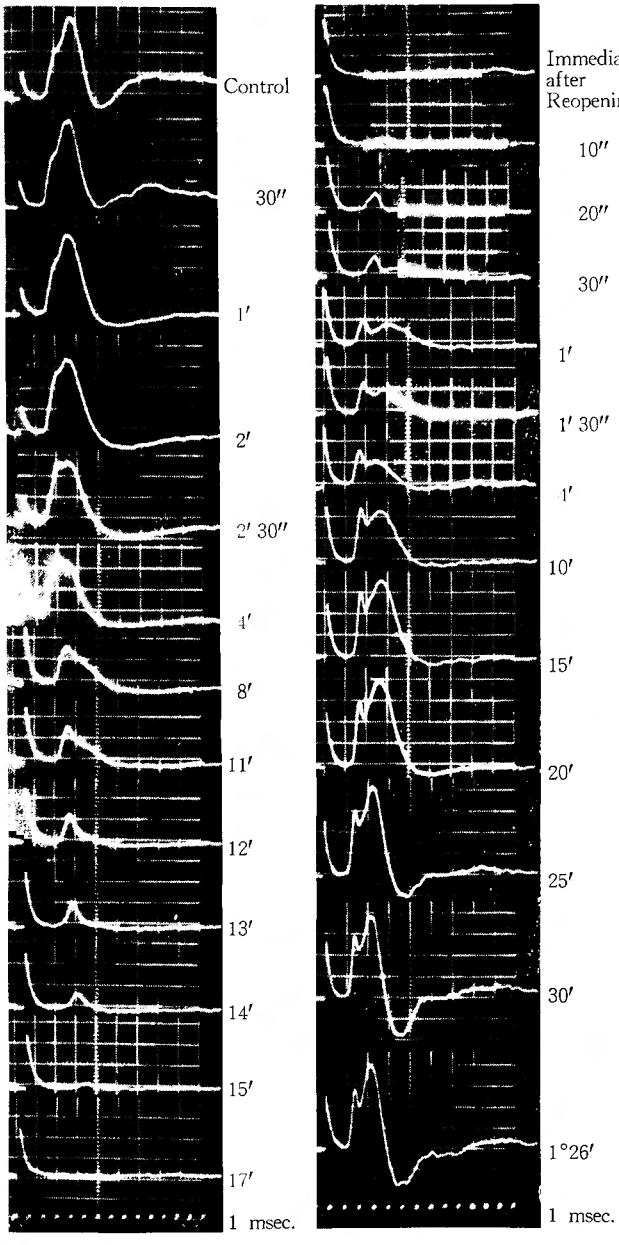


Fig. 3. Progressive Modifications of Responses in the Disappearance Course (Left) and Recovery Course (Right) of the Spike Potential

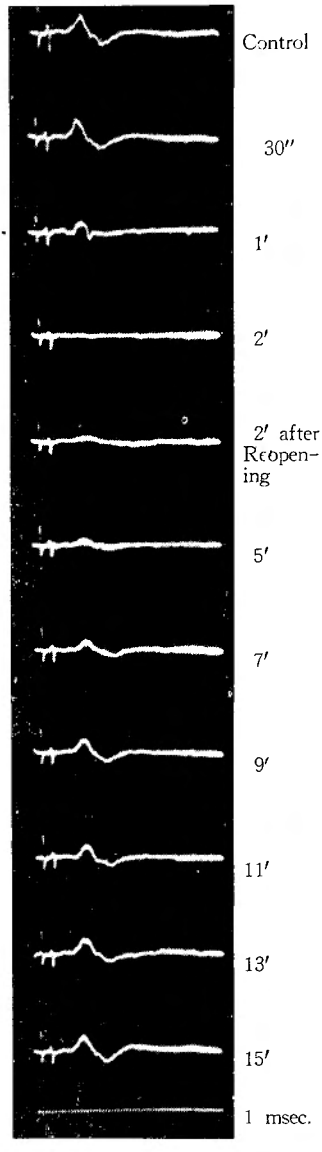


Fig. 4. Progressive Modifications of Responses in Disappearance- and Recovery- Course of Total Response

dog, the time of S disappearance was mostly the same as long as dog's general condition was kept suitable by taking a sufficient rest (30～120min.).

The time of S disappearance was 13～22 min. when the aorta was occluded at various levels between the upper part of the thoracic aorta and the upper part of the

abdominal aorta, but the time of S disappearance was longer than 60 min. when the aorta was occluded at the lower part of the abdominal aorta.

3) Experiment (II) : Modification of electrochordogram due to the aortic occlusion in varied levels of the aorta.

The experiment was to investigate the change of the courses that showed in the preceding paragraph when the occlusion was made in various levels of the aorta. The time of S disappearance and the time of S recovery were used as indicators, because the wave forms in the spinal responses were influenced by the factors described previously.

(a) Experimental method

The aorta was intercepted at several levels. These levels were detected with the help of the scale on the catheter. The aorta occluded at six levels, i. e. the upper, the middle and the lower parts of the thoracic aorta, the midriff, the upper and the lower parts of the abdominal aorta. These levels were confirmed at autopsy.

(b) Results

The time of S disappearance and the time of S recovery at various levels are shown at Fig. 5.

The occlusion at the lower thoracic aorta causes the earliest disappearance of S, and the greater the distance from this level the longer the time of S disapperance in an occlusion level of the aorta. The time of S recovery after reopening of the blood flow was usually less than three minutes when occlusion was made lower than the midthoracic aorta. Only when the occlusion was made at the upper thoracic aorta, the time of S recovery was slow. In other words, the maximum effect of the blood deficiency to the spinal cord appeared when the occlusion was made at the lower thoracic aorta.

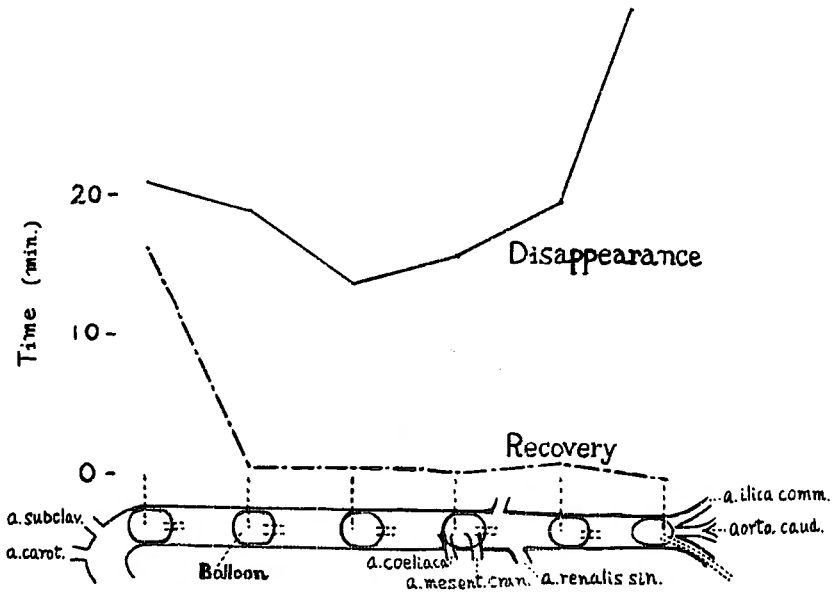


Fig. 5. Progressive Modifications of the Disappearance- and Recovery- Course of the Spike Potential After Intersepting and Reopening the Aortic Blood Flow in Various Levels

Occluded at the upper thoracic aorta, S disappearance time was slow, but once it disappeared, S wave did not easily recover.

When the occlusion was made at the bifurcation of the common iliac arteries, the disturbances of the blood flow to the lumbar cord could hardly be considered, but strangely enough, the amplitude of S decreased remarkably. In this case, too, this amplitude recovered rapidly after the reopening of the blood flow.

4) Experiment (III) ; Under the hypothermia

There must be a positive interrelation between the advent of the paraplegia and the time of S disappearance, so the ways to prolong the time of S disappearance was considered as the preventive measure of paraplegia.

As one of these ways the effect of the hypothermia was examined.

(a) Method

Several ice bags were placed on the back of the dog. The aorta was occluded when the dog's temperatur fell 8°～12°C from the normal temperatur. The measuring of the body temperature was done on the surface of the spinal cord and in rectum.

The lower and upper parts of the thoracic aorta were elected as occlusion levels where maximum effects were given.

(b) Results

The courses of S disappearance and S recovery are shown in Fig. 6. The time of S disappearance was prolonged remarkably under the hypothermia, and the time of S recovery was similar to the case of normothermia.

The result of 17 cases was shown in Table 4.

Table 4 Evaluation of Hypothermia by Means of the Time Required of Spike Disappearances (17 dogs)

Occlusion point	Normothermia			Hypothermia		
Upper thoracic aorta	8′45″	～	22′	24′	～	32′
Lower thoracic aorta	13′	～	15′	16′30″	～	27′

In all cases, the prolongation of the time of S disappearance was observed, i. e. on the average 7′ 30″ prolongation when the occlusion was made at the upper thoracic aorta and 6′ 50″ at the lower thoracic aorta.

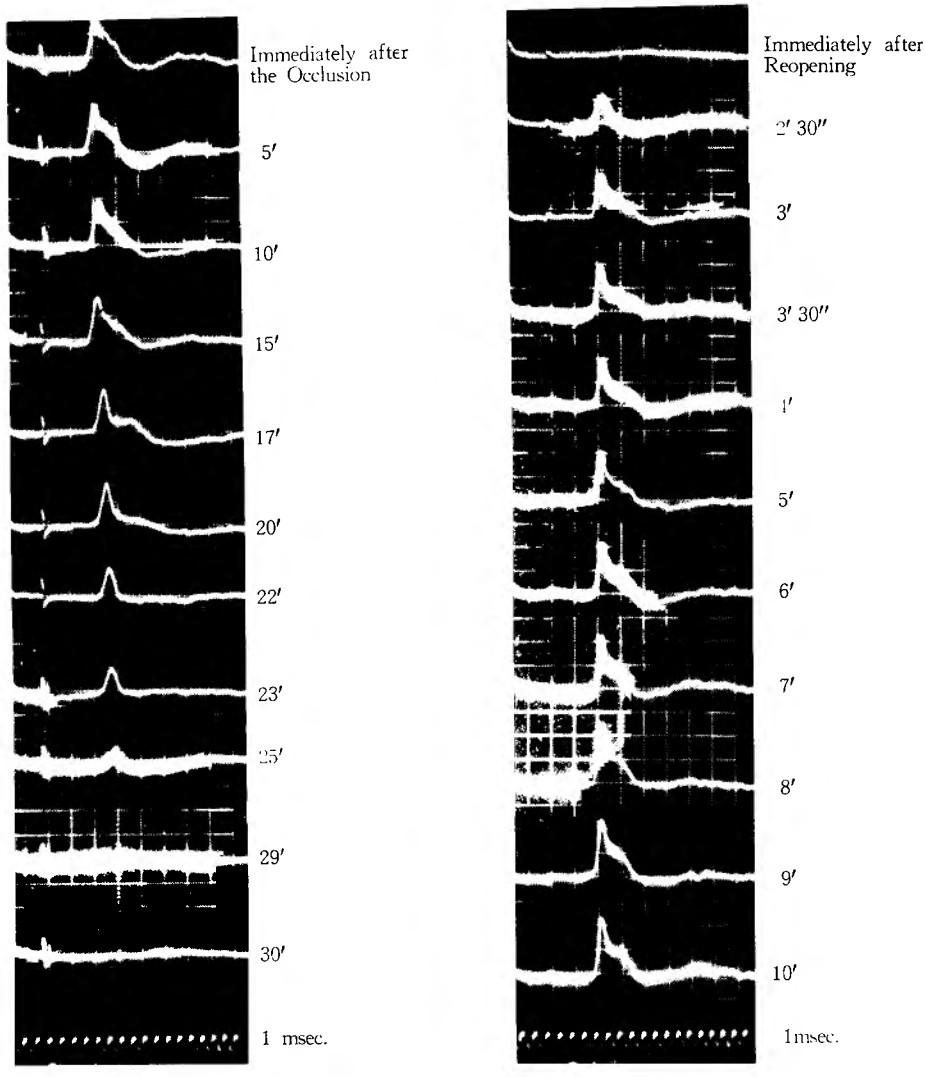
On the other hand, there were three cases in which S recovery was not observed because of undercooling or overcooling.

5) Experiment (IV) ; Combination of normothermia and hypothermia in same dogs

The wave forms of the spinal responses are variable according to the coditions, so the effect of the prolonged time of S disappearance in hypothermia may be influenced by various conditions. Therefore, the experiment was done in same dogs under both normo- and hypothermia. As mentioned above, the time of S disappearance is not influenced under normothermia when the dog was given plenty of time between the first and second aortic occlusion.

(a) Method

The time of S disappearance was measured under the normothermia. After the re-



The Course of S Disappearance After the Aortic Occlusion

The Course of S Recovery After Reopening of the Blood Flow

Fig. 6. Progressive Modifications of the Spike Potentials Under the Hypothermia

Table 5 The Time of Spike Disappearances in Same Dogs

Case	Normothermia	Hypothermia
1	11′	17′
2	15′	17′
3	15′	19′30″

covery the time was measured again under hypothermia. The latter was compared with the former. The occluded level was the upper thoracic aorta.

(b) Results

The experiment was done on three dogs. The results are shown in Table 5. In all cases the time prolonged in hypothermia. In this fact, the effect of hypothermia is undoubted.

6) Experiment (V) ; The Evaluation of oxygen inhalation

According to some investigatiors, the inhalation of high density oxygen before the aortic occlusion is recommended for one of the preventive measures of paraplegia. However no prolongatoin of the time of S disappearance could be observed in this supplementary experiment.

7) Experiment (VI) : The experiment in dog having intact spinal cord

The blood supply to the spinal cord is based upon two main courses, i. e. subclavian artery system and descending aorta system.

In experiment using spinal dogs, the influences from the upper centers could be avoided, but the blood supply from the subclavian artery system was intercepted.

(a) Method

Thoracic spinal cord was not severed. The way of the aortic occlusion was as follows : The aorta was reached from a side of the back, and a string was put around the aorta at just over the opening of the renal arteries as a mark, then the aorta was clamped when necessary. In this way, the blood colour on the surface of the lower half of the lumbar cord changed into dark in a few minutes, and it suggested macroscopically that this part became anoxic. Other procedures were the same as mentioned previously.

(b) Results

Responses were not so clear enough to be analysed evenwhen the stimulus was strengthened or its time of duration was prolonged.

The response disappeared within 30 min. after the aortic occlusion only in one case out of ten dogs. Furthermore, this one case died after two hours without recovery of the cord response though the blood flow was reopened (Fig. 7). As no valuable data was obtained, this experiment was not useful except that it suggested that collateral pass-ways to the spinal cord (lumbar cord) can well develop.

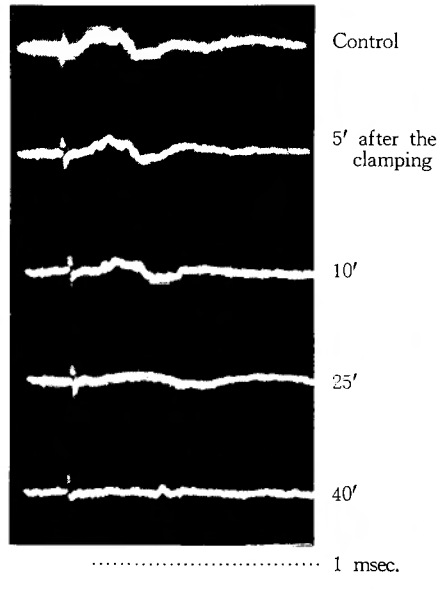


Fig. 7. The Experiments with Non-spinal Dogs (Progressive Modifications of the Cord Potentials)

IV DISCUSSION

There occurs temporary or permanent paraplegia on the lower half of the body accompanied with some surgical operations such as aortic or cardiac surgery. This accidental complication is caused by the transcient interception of aortic blood flow during the ope-

ration. In other words, for the study of preventive measures of this complication, it must be useful to investigate the function of the spinal cord when an artificial occlusion of the aortic blood flow is carried out. In the past, for the purpose of deciding the time limit to tolerate the interruption of the aortic blood flow, the thoracic arota was clamped under the thoracotomy[1)2)11)18)23)24)25)] and the time required for the occurence of paraplegia was observed as an indictor. But in such method the surgical procedures are so great that the dog fall in the respiratory hypofunction or the hypoxia for bleeding, and make it difficult to give a constant result. If the paralysis, which may appear later, is adopted as an indicator, the judgement can not be given without the occurence of paraplagia, and even when it occured, the minimum limit of occlusion time can scarcely be decided.

The occurence of paraplegia is influenced, too, by the individual difference or conditions.

Accordingly, this clamping method is not practical. For example, according to BLALOCK et. al.[1)], there were not a few cases which did not cause paralysis after 40 ~ 50 min. aortic occlusion. According to GROSS et. al.[18)], when there were the factors which demanded the growth of collateral pass way of the blood vessels such as the aortenstenosis, the occurrence of paraplegia needs much more time. But the time limit (15~60 min.) that showed in Table 6 is of great use. This time limit means neither the time until all dogs were paralyzed nor the time escaped from the paralysis.

Table 6 The Durable Time Limits of Aortic Occlusion

Investigators	Time (min.)
Cooley	20 ~ 30
Crafoord	20 ~ 25
Eisenmann	50 ~ 60
Gross et. al.	15
Yamasa et. al.	15 ~ 20

These taken into consideration, the balloon-catheter technique was used to lessen the operative invasion. And the evoked electrochordography was chosen as an indicator to forecast the paralysis.

Spinal cord potentials were first recorded by GASSER and GRAHAM in 1933[8)], since then, the evoked electrochordography has attracted our attention. They thought about each component of the response as follows: The first is a spike originating in the intramedullary dorsal root fibers. The second is a slow negative potential wich means the postsynaptic interneuronal activity, though there are some different opinions on the origin of this deflection. The last one is positive after potential, and this deflection is postsynaptic origin but has not been assigned as yet to any specific unit in the spinal cord.

These responses represent maximum amplitude at the level of L_7 and S_1 when an antidromic impluse volley is delivered, but they are able to be recorded satisfactorily at other levels as well as at the level delivered by this impulse volley (out side the entry zone). According to BERNHARD the potential of responses diminish its amplitude symmetrically and regularly delay its time interval to appear following the stimulation as the distance from the stimulated zone increases, but in this case the influence on these 3 com-

ponents is not similar. The author could ascertain the fact experimentally.

On the other hand, it is said that after the spinal cord is severed, negative potential diminishes in amplitude and positive potential almost disappears, but it recovers in more than two hours. Similar results were obtained on cats, dogs and monkeys. Based upon these reasons, the pint which records the maximum amplitude of S was regarded by the author as entry zone. This point exists at the lowest part of lumbar vertebra level. The reasons that S was adopted as an indicator in this experiment are as follows:

i. In S, N and P, the attiude of S under aortic occlusion coincides with the time limit of paralysis (15～60 min) under clamping method.

ii. S is considered to show the activity of A fiber which innervates the somatic function of the lower extremities.

iii. S appeares clearly all the time.

iv. The resistance of A fiber to the anoxia ranks second in each fiber of the mixed nerve, i. e. the first is C fiber, the second A fiber and, the third B fiber.

Therefore, S is considered suitable to choose as an indicator of the mixed nerve.

In Experiment (1), the details of A, S, N and P deflections, especially S deflection was investigated.

As is shown in figures, S deflection consists of single or multiple tips, commonly of two tips as designated S_1 and S_2. As to the resistance to anoxia S_1 is more durable than S_2, so S_1 can practically be adopted as an indicator.

In disappearance and recovery of S under the disturbance of the blood circulation, the former occurs slowly and the latter rapidly. The course of S disappearance after the onset of aortic occlusion begins with a slight increase of the amplitude followed by a slow decrease, and ends in relative quick decay.

The latency has not a regular trend in increase or decrease until shortly before the disappearance. If the disappearance time is divided into two stages, in the former half the latency varies little in any duration of occlusion time showing no regular tendency. In the latter half the latency prolongs gradually and finally disappears.

In case of two tipped S (S_1 and S_2), after the onset of the aortic occlusion, S_2 is very predominant at the beinning, but S_2 decreases the amplitude in course of occlusion time, while S_1 keeps a constant level, and at the end of the former half of disappearance time S_1 becomes predominant. In the latter half of disappearance time, S_1 decreases the amplitude gradually and then both of S_1 and S_2 disappear.

The time of S disappearance after the onset of the aortic occlusion is 13～22 min. at the levels between the upper thoracic and the upper abdominal aorta. S did not appear one hour after the onset of occlusion at the lower abdominal aorta, but its amplitude remarkably decreased.

Even in the occlusion of the aorta in such a lower level the lumber cord potentials are influenced. Although the S disappearance means the standstill of the neuronal activity of the spinal cord, it does not represent the clinical pictures of spinal paralysis.

After the reopening, the amplitude and duration time of S quickly increase in the former half of the recovery time, while in the latter half S once increases them more than control, then decreases them slightly and finally approaches the control.

The latency is usually almost similar with the control after the beginning of the recovery or approach the control after small fluctuations.

The patterns of S_1 and S_2 in the recovery take the reverse course of the disappearance.

In this way if enough time is given after S recovery, the experiment of occlusion can be repeated, and the time of S disappearance is almost the same. That is to say, if S recovers completely, the recovery course of N and P can be ignored in the repetition of the occlusion experiments.

In Experiment (II), it is proved that these courses are varied by changing the part of aortic occlusion. The earliest disappearance of the spike deflection is caused by the occlusion at the part of the lower thoracic aorta. That is to say, this aortic level is "the functional watershed of the spinal circulation". The similar results were obtained by IKEDA in our clinic by the electropolarographic study on the oxygen availability of spinal cord in circular disturbances.

In this experiment, the blood flow to the spinal cord is influenced by the blood pressure. It is a matter of course that the higher the blood pressure of the proximal part of aortic occlusion, the larger blood flow runs into collateral vessels.

According to IKEDA, the aortic level at the opening of the celiac artery is an important borderline in the aortic occlusion : when the occlusion of aorta is carried out above the opening of celiac artery spinal blood flow always increases, but when the occlusion is done below the celiac artery orifice no increase of the spinal blood flow is observed.

On the other hand, the comparision of the recovery was done by choosing the time of S reappearance as an indicator because the judgement can be done clearly. Consequently the reappearance time is prolonged when the aortic occlusion on the upper thoracic level is reopened, while when reopened the occlusion on the lower level S appeared within two minutes. This shows that the blood interception at the upper thoracic aorta is more dangerous than the other parts for the spinal circulation. From the above-mentioned facts, we consider that the collateral blood supply to the spinal cord borders at the lower part of the thoracic aorta, and the collaterals in the upper or lower parts take different courses, and each of them are relatively well developed[14].

According to experiment (III), the infliction of hypothermia caused the delay of the time of S disappearance.

It is also a preventive measure of paraplegia[6]. During these experiments, three cases which did not recover S potential under the overcooling or the undercooling were experienced and the optimum temperature of the hypothermia in the dog is considered to exist at the points about $8° \sim 10°C$ lower than the normal body temperature (normal body temperature is about $38°C$ in the rectum in a dog).

Experiment (IV) ascertains that the effect of hypothermia is not influenced by the individual difference or other conditions.

Experiment (V) shows that the temporary inhalation of high density oxygen does not cause the delay of time of S disappearance.

Experiment (VI) shows that when the spinal cord is not severed, the clear responses can hardly be recorded. So, on applying this to patients for the forecast of the paralysis,

many further studies are needed.

V CONCLUSION

For the sake of finding the clue on the hemodynamics of the spinal cord, the temporary aortic occlusion was performed in dogs. Evoked electrochordogram at the lower lumbar cord was used as an indicator of the neurophysiological judgement. In addition, the author investigated the preventive measures for the occurence of paraplegia in the circular lesion of the spinal cord.

The results are as follows:

1) The spinal blood flow has a functional watershed at the lower part of the thoracic aorta. The aortic occlusion at this level caused the most effective blood deficiency on the lumbar segment of the spinal cord.

2) When the aortic occlusion was done in spinal dogs, in three components of the evoked electrochordogram at the exposed lumbar cord, spike disappears in 13～22 minutes, the negative and positive potentials in 0.5～3.0 minutes. On the other hand, revovery of S begins early and N and P slowly.

3) The hypothermia has an effect on the prolongation of the time of spike disappearance, and it suggests that the hypothermia is valuable for the preventive measure of the paraplegia due to aortic occlusion. The overcooling hypothermia is sometimes harmful showing that there is an optimum temperature.

4) High density oxygen inhalation before the aortic occlusion is not effective for preventing spinal paraplegia.

5) Electrochordography is beneficial for the forecast of the postoperative paraplegia, but on applying this to man, further studies are needed.

Acnkowledgement

The author is greatly indebted to prof. C. KIMURA for his cordial guidance and encouragement throughout the course of this investigation and to Dr. K. TSUNEKAWA for much valuable advice. He also wishes to thank to Drs. Y. UCHIDA, M. IKEDA and S. YAMAJI for their help and cooperation.

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和文抄録

Electrochordogram による脊髄血行動態の研究

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脊髄血行動態解明並びに脊髄障害対策の一助とすべく本研究を行なつた．実験動物は約40頭の健康な雑種成犬で，実験は夏期室温下で行ない，以下の結論を得た．

なお，実験に際して，脊髄の血行障害をもたらす方法としてバルーンつきカテーテルによる大動脈血流の一時的遮断を行ない，神経生理学的指標としては脊髄犬における腰髄の誘発活動電位を利用した．

1) 脊髄血行は，胸大動脈下部にその機能的分水嶺を有し，この点での血流遮断が腰髄に対する最も大きな阻血効果を示した．

2) 脊髄犬において，大動脈を遮断すると腰髄誘発活動電位は次第に消失するが，その三成分の消失過程は同一ではない．即ち，Spike の消失時間は13～22分で，Negative 及び Positive potential の消失時間は30秒～3分である．一方，血流の再開によつて，前者の回復は急速に始まり，後二者の回復は著しく遅い．

3) 低体温法は Spike の消失時間を延長させるのに明確な効果を示し，大動脈血流遮断を要する手術などの場合，それにより招来される麻痺（主に下肢）の予防法として有益であることを暗示する．しかし過冷却は反つて有害なことがある．

4) 大動脈遮断前の一過性酸素吸入の効果は認められなかつた．

5) 脊髄電位の観察は，術後の麻痺予測に資する方法と思われるが，人体応用には更に工夫を要する．

（本論文の要旨は，1964年，盛岡における第23回日本脳神経外科学会総会で報告した．）